FIG. 1

FIGURE 2. OPTIMAL SEQUENCING METHOD

Table 1

TRIAL	PROBLEM	RESPONSE	RESPONSE ACCURACY	RESPONSE TIME (sec)	COMMENT
1	7 X 7 =	"49"	CORRECT	3.5	Fast, correct response.
2	6 X 7 =	"38"	WRONG	--	Incorrect response.
3	7 X 4 =	"28"	CORRECT	18.4	Correct but slow.
4	12 X 7 =	"72"	WRONG	--	
5	6 X 7 =	"42"	CORRECT	11.7	Recurrence of problem missed on Trial 2.
6	9 X 9 =	"72"	WRONG	--	
7	12 X 7 =	"84"	CORRECT	10.4	Recurrence of problem missed on Trial 4.
8	5 X 8 =	"40"	CORRECT	2.6	
9	9 X 9 =	"80"	WRONG	--	
10	7 X 4 =	"28"	CORRECT	6.1	Recurrence of problem answered slowly on Trial 3.
11	6 X 3 =	"18"	CORRECT	4.8	
12	9 X 9 =	"74"	WRONG	--	Recurrence of problem missed on Trial 9.
13	3 X 4 =	"12"	CORRECT	2.4	
14	6 X 7 =	"32"	WRONG	--	
15	9 X 9 =	"81"	CORRECT	4.5	Recurrence of problem answered slowly on Trial 5.
16	7 X 7 =	"49"	CORRECT	2.7	Recurrence of problem missed on Trial 12.
17	12 X 7 =	"84"	CORRECT	6.2	Recurrence of problem answered quickly on Trial 1.
18	6 X 7 =	"42"	CORRECT	5.1	Recurrence of problem answered slowly on Trial 7.
19	3 X 10 =	"30"	CORRECT	3.2	Recurrence of problem missed on Trial 14.
20	7 X 4 =	"28"	CORRECT	3.9	Recurrence of Trial 10 problem.

Figure 3. Sample Sequence of Trials Using the Sequencing Algorithm. Relevant parameter values: $a = 1$, $b = 2$, $D = 2$, $W = 12$, $K = 1$. Arrows indicate selected examples of problem recurrence. (See text.)

TRIAL

PROBLEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7 X 7 =	(1)	-.088	0	.088	.176	.264	.352	.44	.528	.616	.704	.792	.88	.996	1.06	(1.14)	.076	.151	.226	.30
6 X 7 =	1	(1)	-.12	0	(1.2)	-.148	0	.148	.296	.444	.592	.74	.888	(1.04)	-1.2	0	.12	(2.4)	.11	.22
7 X 4 =	1	1	(1)	-.2	0	.202	.404	.606	.808	(1.01)	-.129	0	.129	.258	.387	.516	.645	.774	.903	(1.03)
12 X 7 =	1	1	1	(1)	-1.2	0	(1.2)	-.158	0	.158	.316	.474	.632	.79	.948	1.10	(1.28)	.123	.245	.368
9 X 9 =	1	1	1	1	-1.2	0	-1.2	0	(1.2)	-1.2	0	(1.2)	-1.2	0	(1.2)	.102	.204	.307	.409	.511
5 X 8 =	1	1	1	1	1	1	1	(1)	.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.85
6 X 3 =	1	1	1	1	1	1	1	1	1	.158	.316	.106	.212	.318	.424	.530	.636	.742	.848	.954
3 X 4 =	1	1	1	1	1	1	1	1	1	1	(1)	1	1	.068	.137	.205	.273	.341	.409	.477
3 X 10 =	1	1	1	1	1	1	1	1	1	1	1	1	(1)	1	1	1	1	1	(1)	.083
8 X 4 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4 X 12 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3 X 9 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8 X 7 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11 x 5 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6 X 8 =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
...																				

Figure 4 Priority Scores by Trial for Sample Sequence in Figure 3. Columns indicate trials; rows show a partial list of problems in the database. Circled priority scores indicate the problem chosen by the algorithm for that trial. Parameter values: a = .1; b=2; W=12; D=2; k=1; r=2

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TRIAL	PROBLEM	RESPONSE	RESPONSE ACCURACY	RESPONSE TIME (sec)	COMMENT
1	camino	"road"	CORRECT	3.5	Fast, correct response.
2	Martes	"March"	WRONG	--	Incorrect response.
3	dos	"two"	CORRECT	18.4	Correct but slow.
4	verde	"Don't know"	WRONG	--	
5	anaranjado	"angel"	WRONG	--	
6	Martes	"Tuesday"	CORRECT	15.0	Recurrence of problem missed o
7	Abril	"April"	CORRECT	10.4	
8	facil	"easy"	CORRECT	2.6	
9	verde	"green"	CORRECT	9.7	Recurrence of problem missed o
10	anaranjado	"apple"	WRONG	--	Recurrence of problem missed o
11	Viernes	"Friday"	CORRECT	4.8	
12	azul	"blue"	WRONG	--	
13	dos	"two"	CORRECT	2.4	Recurrence of problem answere
14	Noviembre	"November"	CORRECT	8.6	
15	anaranjado	"orange"	CORRECT	11.3	Recurrence of problem missed o
16	cero	"zero"	CORRECT	2.7	
17	camino	"road"	CORRECT	6.2	Recurrence of problem answere
18	Martes	"Tuesday"	CORRECT	5.1	Recurrence of problem answere
19	hija	"daughter"	CORRECT	3.2	
20	empujar	"orange"	WRONG	--	

Figure 5. Sample Sequence of Trials Using the Sequencing Algorithm with Parameters Set to Favor Introduction of Relevant parameter values: a = .1, b = 1.5, D = 2, r=2, W = 6, K = 1.2.

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TRIAL

PROBLEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
camino	(1.2)	-.09	0	.09	.18	.27	.37	.46	.55	.64	.73	.82	.92	1.01	1.1	1.19	(1.29)	-.09	0	.09
Martes	1.2	(1.2)	-0.6	0	0.6	(1.2)	-0.14	0	.14	.28	.42	.56	.70	.84	.98	1.11	1.25	(1.39)	-.08	0
dos	1.2	1.2	(1.2)	-0.16	0	.16	.32	.49	.65	.81	.97	1.13	(1.3)	-.12	0	.12	.25	.37	.49	.61
verde	1.2	1.2	1.2	(1.2)	-0.6	0	.6	1.2	(1.8)	-0.12	0	-0.12	.23	.345	.46	.58	.69	.81	.92	1.04
anaranjado	1.2	1.2	1.2	1.2	(1.2)	-0.6	0	.6	1.2	(1.8)	-0.6	0	.6	1.2	(1.8)	-.12	0	.12	.25	.37
Abril	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.08	0	.08	.17	.25	.34	.42	.51	.59	.68	.76	.85	.93
facil	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.09	0	.09	.18	.27	.37	.46	.55	.64	.73	.82	.92
Viernes	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.16	0	.16	.33	.49	.66	.82	.99	1.15
azul	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.07	0	.07	.13	.20	.26	.33	.40
Noviembre	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.11	0	.11	.22	.33	.44
cero	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.09	0	.09	.19
hija	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.6	
empujar	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	
amarillo	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Lunes	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
rosado	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

FIGURE 6. Priority Scores by Trial for Sample Sequence in Figure 5. Columns indicate trials; rows show a partial list of problems in the database. Circled priority scores indicate the problem chosen by the algorithm for that trial. Parameter values: a = .1; b=1.5; W=6; D=2; k=1.2; r=2.

FIGURE 7. PERCEPTUAL LEARNING MODULE

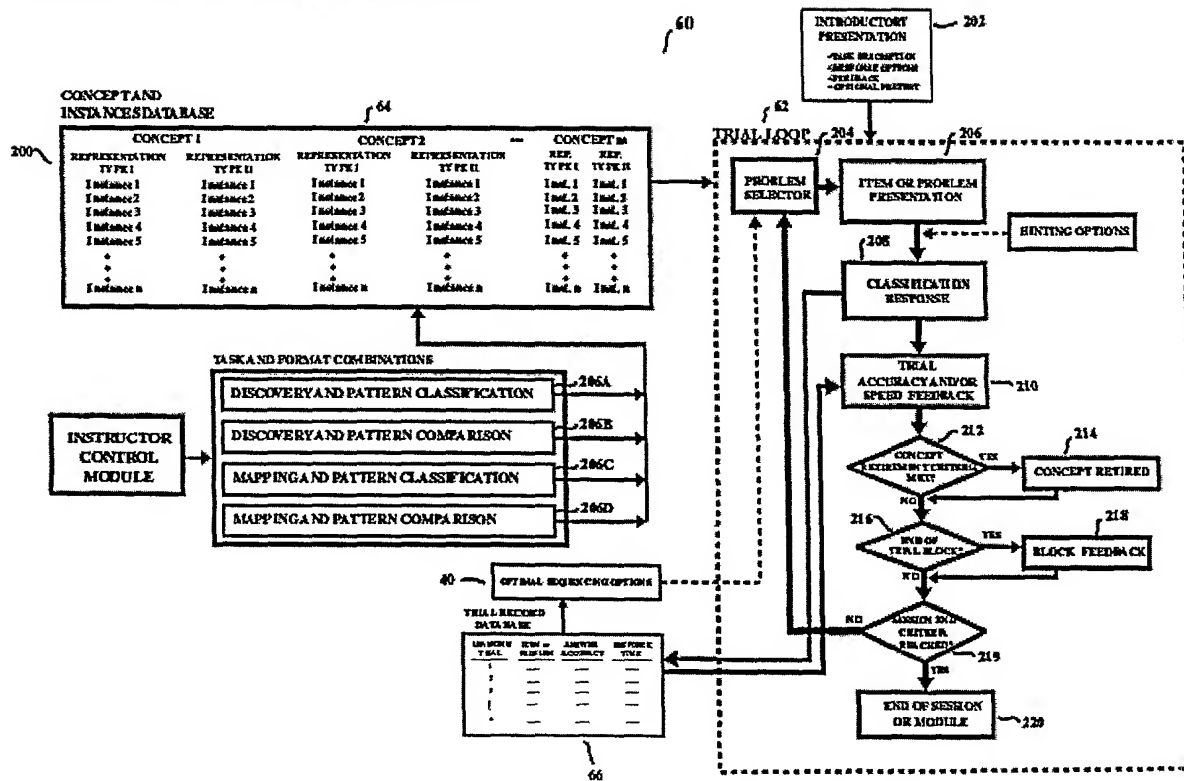**FIGURE 8.** PERCEPTUAL LEARNING SYSTEM: *STRUCTURE DISCOVERY* VARIANT
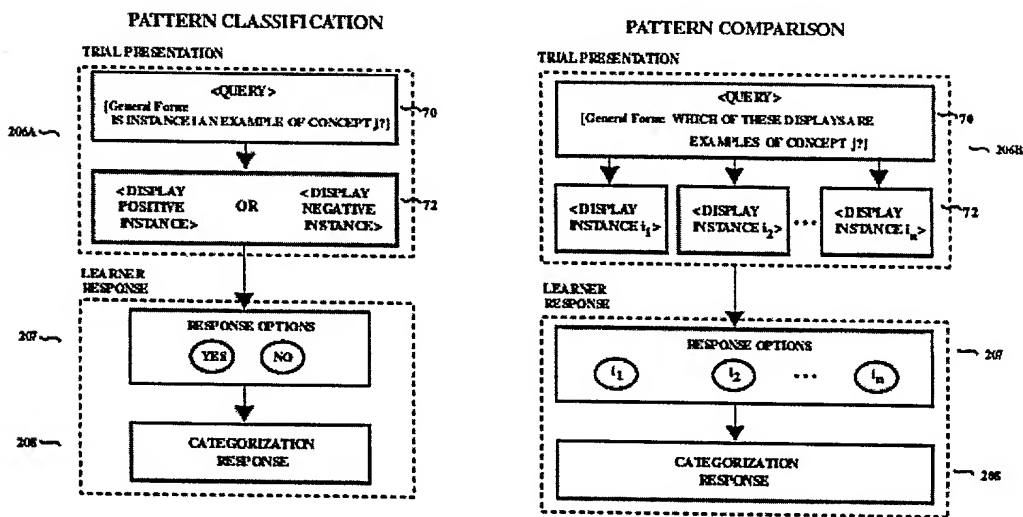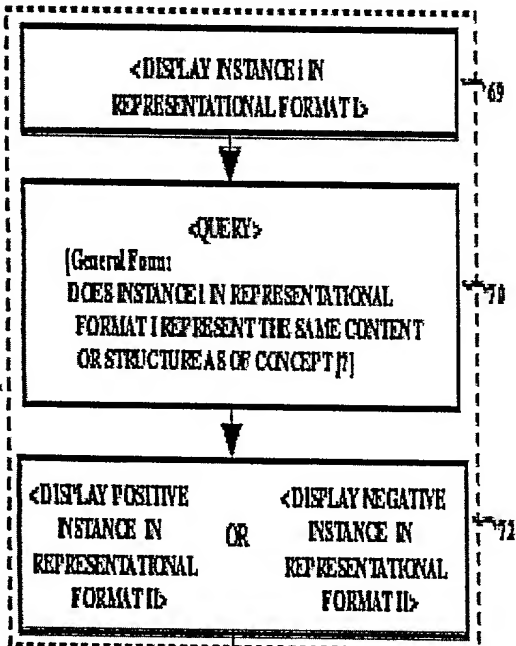
PROBLEM PRESENTATION FORMATS - DETAIL

PATTERN CLASSIFICATION

PATTERN COMPARISON

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FIGURE 9. PERCEPTUAL LEARNING SYSTEM: *STRUCTURE MAPPING* VARIANT

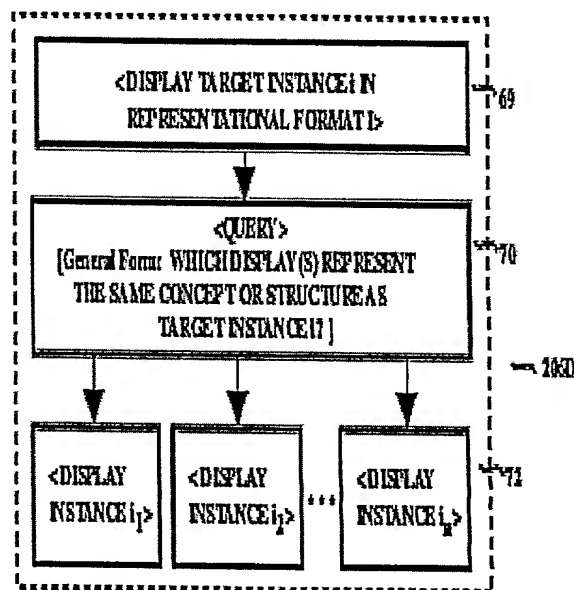## PROBLEM PRESENTATION FORMATS - DETAIL

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Inventor(s): Philip J. Kellman, Ph.D.
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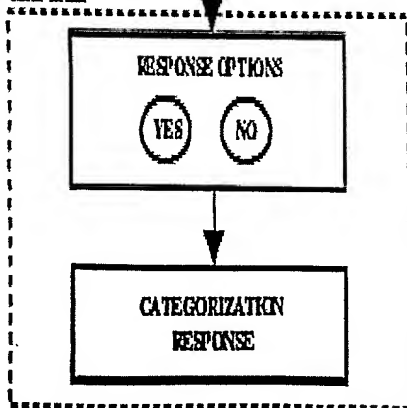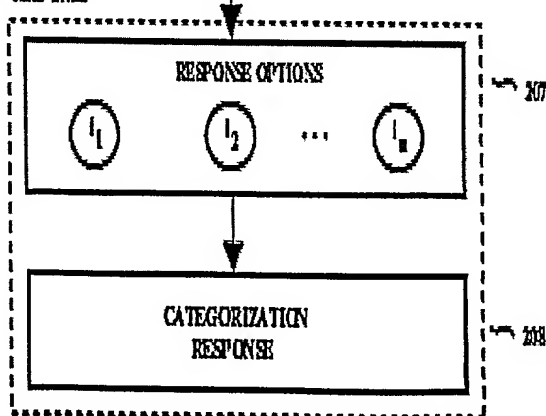
FIGURE 10

HINTING ALGORITHM: OVERVIEW

TRIAL LOOP —90

ITEM OR PROBLEM PRESENTATION —300

SUBJECT RESPONDS IN N SECONDS? —310

HINT CATEGORY SELECTOR —320 —82

LEARNER ENTERS RESPONSE —340

WITHIN-CATEGORY HINT SELECTOR —84

RESPONSE CORRECT? —312

HINT PRESENTATION 330

LEARNER ENTERS RESPONSE 340

TRIAL RECORD DATABASE —86

HINT DATABASE

TRIAL ACCURACY AND/OR SPEED FEEDBACK —350

END OF TRIAL —360

88

82

HINT CATEGORY SELECTOR

402

INITIAL CATEGORY PRIORITY SCORE ASSIGNMENT

$$\forall i \ (CP_i = 1)$$

(All category priorities are initially set to 1.)

404

CATEGORY SCORE PRIORITY UPDATER

406

AFTER EACH TRIAL,
FOR EACH PROBLEM OR TYPE i

WAS HINT CATEGORY i USED ON LAST TRIAL?

YES → $CP_i = .5$

NO → $CP_i = 1$

HINT DATABASE for PROBLEM OR CONCEPT j

88

CATEGORY PRIORITY SCORES

CP_1	CP_2	CP_3	CP_i
CATEGORY 1 HINTS	CATEGORY 2 HINTS	CATEGORY 3 HINTS	... etc.

408

WEIGHTED RANDOM SELECTOR

400

HINT REQUEST

(FROM TRIAL LOOP)

WEIGHTED RANDOM SELECTION OF HINT CATEGORY SUCH THAT:

$$p(C_i) = CP_i / CP_{total}$$

440

84

WITHIN CATEGORY HINT SELECTOR

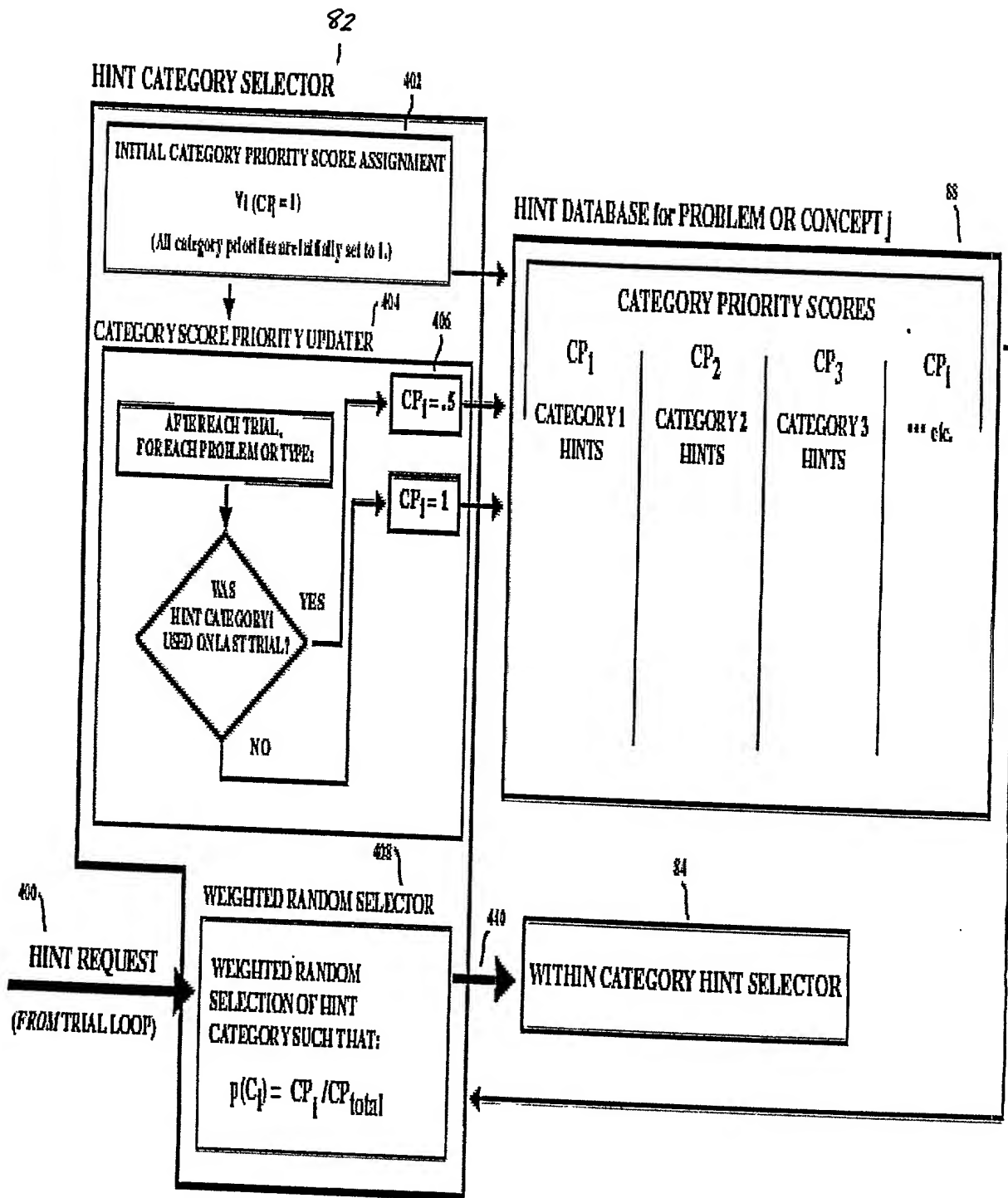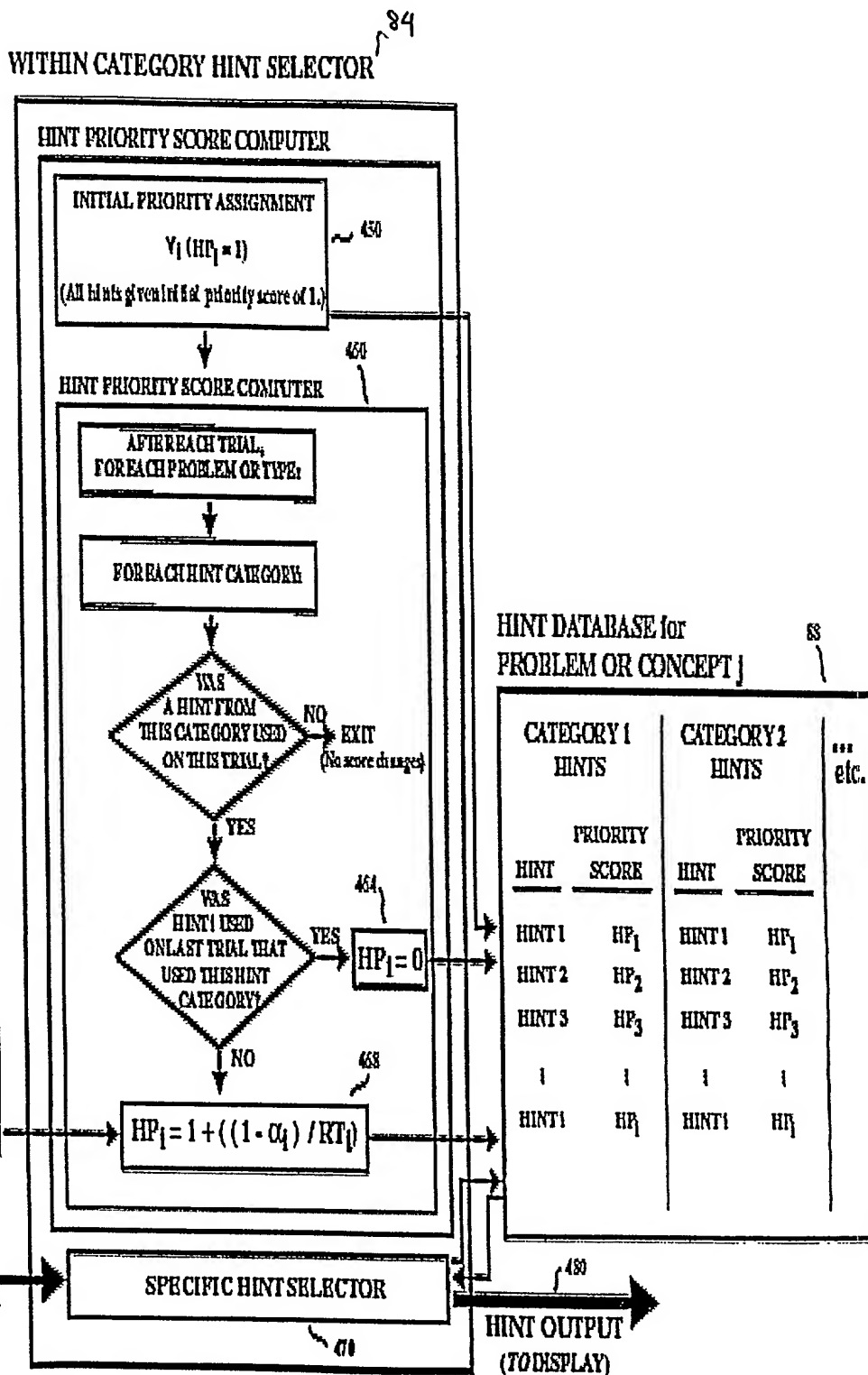**FIGURE 11. HINT CATEGORY SELECTOR**

84

WITHIN CATEGORY HINT SELECTOR

FIGURE 12. WITHIN-CATEGORY HINT SELECTOR